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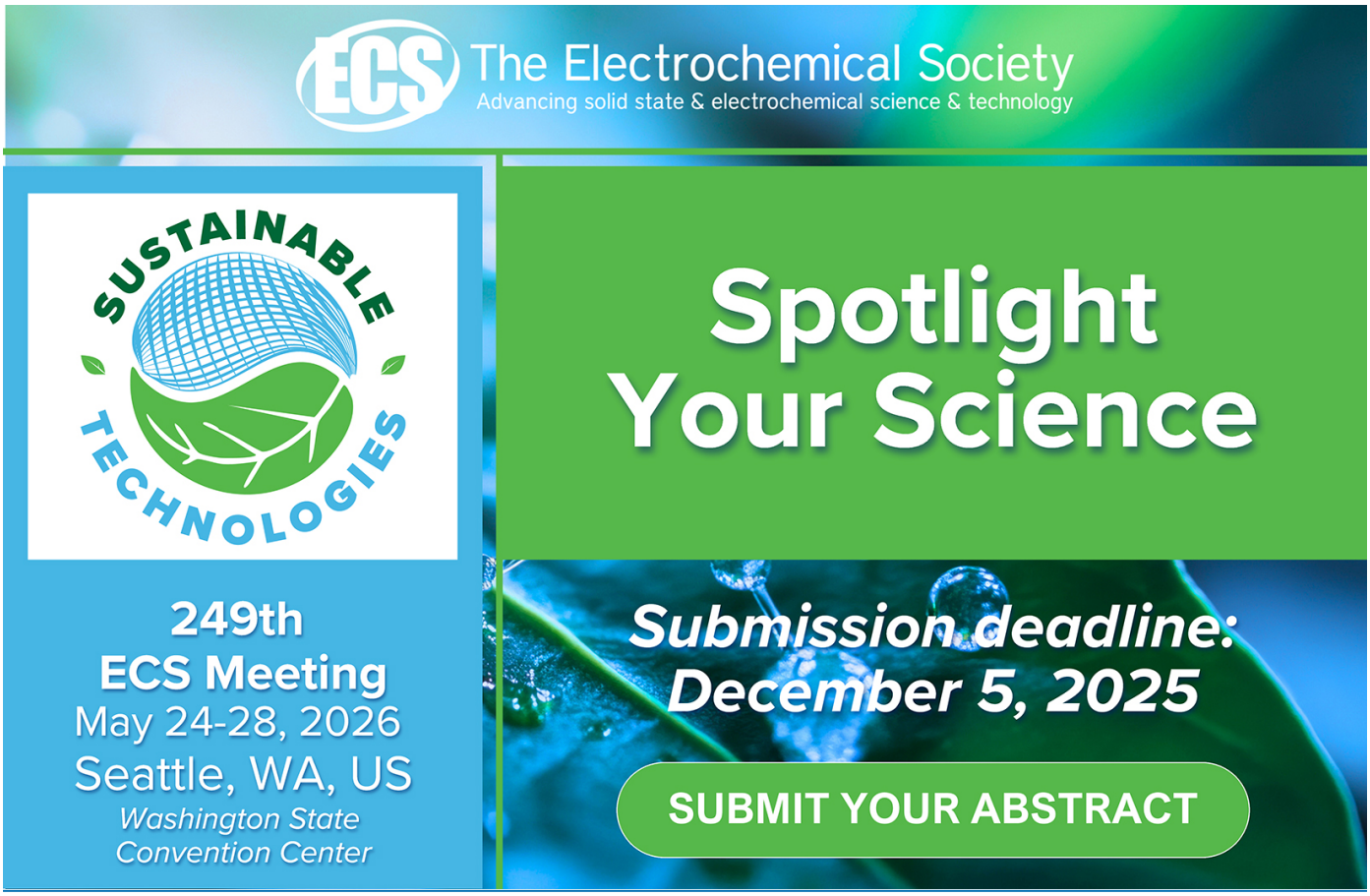
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Analysis of energy saving in a single-family home project

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Abstract. Electric energy is one of the types of energy that is most present in the activities that human beings carry out daily, hence the importance of making efficient consumption of this resource, especially that which is done in homes, since energy savings represent a reduction in carbon dioxide emissions. Given that the construction sector can represent up to 39% of the carbon dioxide emissions emitted into the atmosphere, this research analyzes the impact generated by the construction and use of a single-family home, with the use of DesignBuilder software. Initially, a model was made under traditional conditions, thus determining where the greatest heat gains were concentrated, followed by a second model under adjusted conditions. A life cycle analysis was made under conditions adjusted to a period of 100 years and the submission of the two conditions to the choosing by advantages method. The results showed that the changes can reduce annual energy consumption by up to 66% and recover the investment in 10 years. Finally, the analysis of the life cycle determined that for a period of 100 years the emissions are 18679.67 equivalent tonnes of carbon dioxide.

1. Introduction

At present, there is a concern about the growth model that is being developed around the world, since with the accelerated increase in the world population, the increase in consumption has been directly proportional, leading as a result to significant changes on planet earth such as They are deforestation, scarcity of water, natural resources and food, extinction of animals and long periods of floods and droughts. The construction industry significantly affects the environmental field since it impacts natural resources and ecosystems, in the same way the social field, because it impacts the health and quality of life of people, likewise the economic field because it provides sources income as well as infrastructure

The construction sector is one of the sectors that contributes significantly to the carbon footprint generated by humanity, representing up to 39% of the carbon dioxide (CO_2) emissions emitted into the atmosphere [1-3], in order to stop this problem, strategies have been created that seek to use materials that generate less environmental impacts [4]. One way to quantify the impacts on the construction of a project before executing it is the development of specialized software models, in this case through the DesignBuilder software [5,6], which was used to determine the energy-thermal performance of this project a two-level single-family house through an integrated design, where initially an analysis of the geometry of the structure was made, followed by the materials and internal loads defined such as the equipment and occupants, later the evaluation and analysis of results was made to create and implement strategies in a new model with which is expected to obtain favorable results.

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At present, the circular economy has taken on great importance and with this, it has begun to speak on a large scale of the life cycles of a product and a project, the first is denoted as the consecutive and interrelated stages of the system of a product, from the acquisition of raw materials or generation from natural resources until their final disposal [7] and the second as the set of phases in which a project is organized from its inception to its closure [8]; in general terms we can say that the life cycle of a project is contained in the life cycle of a product, this is how a life cycle analysis for housing was subsequently carried out [9-11], based on Environmental declarations of products for 100 years of the useful life of the infrastructure, identifying the CO_2 equivalent emissions of each product necessary for the construction of the house and the quantities necessary to quantify the total emissions. Since every project can be developed from multiple alternatives, the evaluation of these can be done from many methods that allow an objective, efficient and effective selection, for this case two alternatives were evaluated using the choosing by advantages (CBA) method [12], complemented with a cost study, analyzing the return period of the investment of the selected alternative.

2. Methodology

For the development of the project, it was necessary to follow the procedure outlined in Figure 1.

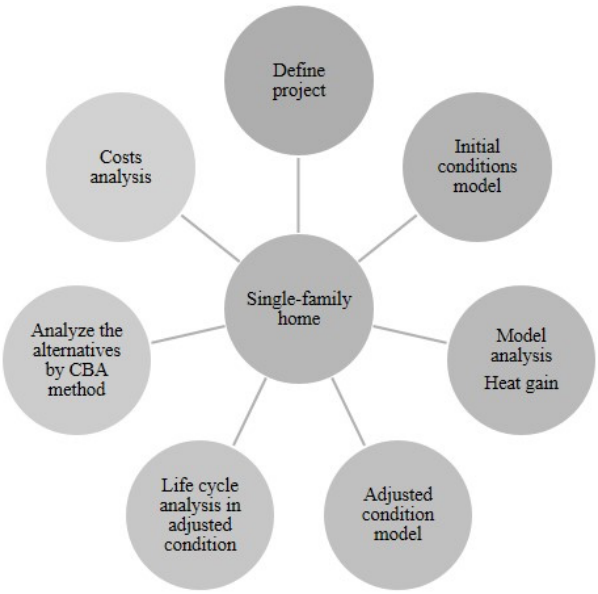


Figure 1. Processes for research development.

Initially, the type of project is defined, as well as the materials and loads for the initial study conditions, this research was carried out taking as a reference a two-level single-family house built with traditional materials, loaded the respective specifications in the DesignBuilder software, we proceed to Execute the model, the results are analyzed in order to identify where the greatest heat gains are concentrated and thus be able to plan the respective strategies that lead to improve the initial conditions, the highest concentrations of heat in this project are found in lighting by Therefore, the respective changes are focused on changing the type of luminaires as well as the installation of the ceiling in the slabs of the building, once the respective adjustments have been made, the model is executed for the second time, expecting significant changes in heat losses and gains, later we proceed to do an life cycle analysis (LCA) through the use of materials with their respective environmental product declaration (EPD), this analysis was developed considering a period of life of the property of 100 years. To know another result parallel to the models, the two alternatives were subjected to a selection method by advantage in which it was necessary to define some factors, criteria, and weighting values for each of the factors to be considered. Finally, a cost analysis is carried out to know what the return period of the investment is made by the adjustments of alternative 2.

3. Results

The analysis project was a two-level structure, for single-family residential use, see Figure 2; the model in initial conditions was raised under basic construction conditions using materials that have an environmental declaration, as well as equipment and appliances for general use, to know the behavior of heat gains and losses in this type of structure.

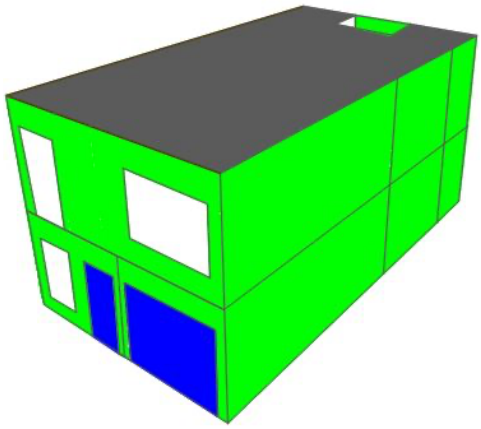


Figure 2. Simulation base model in DesignBuilder.

In Figure 3 we can see how the highest heat gains in the home are obtained through lighting, cooling, and operation of equipment with values of 56.76 KW·h/m^2, 41.84 KW·h/m^2, and 4.06 KW·h/m^2 respectively, these variables are those that must be evaluated and improved with significant changes, due to the climate conditions of the region (Temperate). The model in tight condition was executed by adjusting, including installing a drywall ceiling on both levels of the house, in addition to changing the type of lighting in the building, with the aim of optimizing heat gains and losses in the structure.

In Figure 4 you can see the considerable reduction in heat gains due to changes in the structure. The values are 37.84 KW·h/m^2, 41.08 KW·h/m^2 and 4.06 KW·h/m^2 respectively, achieving a 66% reduction in the energy of the luminaires, in the other two aspects they remain constant.



Figure 3. Result of the model in initial conditions.

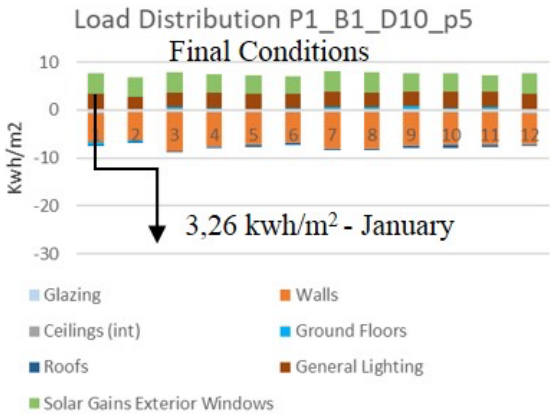


Figure 4. Result of the model in final conditions.

Life cycle analysis (LCA) is a tool that allows quantifying the impacts generated by the manufacture of a product at all times of its useful life [13]. LCA results are used to classify products according to their emissions, thanks to the environmental product declarations (EPD) [14-16]. DAPs are voluntary declarations where environmental information about the life cycle of a product is disseminated, for the

evaluation of the life cycle of the single-family home under study, EPD published in [17] were used, taking into account the emissions of CO_2 equivalent for 100 years of useful life of the house, in Table 1 you will find the list of materials, their EPD registration number, their study unit and the emissions generated in each activity.

Additionally, the emissions generated by electricity consumption of the selected alternative were considered, by means of a greenhouse gas calculator the annual consumption of 83.73 KW·h/m^2 was transformed into 2326.53 Kg CO_2 equivalent, with this it was possible to determine that the emissions generated by the construction and use of the house for a period of 100 years is 25133.04 Tons of CO_2 equivalent.

Table 1. Construction materials LCA [17].

Material	EDP registration number	Study unit	CO_2 equivalent * Study unit	Quantity	Total emission
Steel	S-P-00704	Tom	605.00	3.65	2209.53
Concrete	S-P-00896	M^3	2.67E+02	30.67	8189.90
Ceramics	S-P-01310	M^2	25.00	108.27	2706.75
Stucco	S-P-00584	KG	1.13E-01	757.84	85.64
Brick	S-P-00750	3731 bricks	2.83E+02	0.97	273.22
Roof sheet for over roof	S-P-00429	M^2	3.30E+02	63.77	394.23
Mortar	S-P-00897	M^3	1.42E+02	4.32	613.44
I stick ceramic	S-P-1677	KG	3.38E-01	360.90	122.00
Painting	S-P-01853	M^2	4.28E-01	287.98	123.26
Wooden door	S-P-01392	UND	2.00E+02	8.00	1600.00
Pressure pvc pipe	S-P-00718	KG	4.54776	11.20	50.93
Sanitary pvc pipe	S-P-00716	KG	3.7004818	52.82	195.46
Windows	S-P-01749	UND (1230 mm×1480 mm)	352.55180	6.00	2115.31
Kg $CO_{2\ eq}$					18679.67

The different alternatives are generally proposed in order to satisfy the context and the purpose for which they were created. One of the methods used in the market is to choose by advantages or the better-known CBA Method [18-20], which initially consists of in generating factors to which an importance criterion will be assigned later, defining the factors and criteria, the attributes of each of the proposals are compared, indicating the variables of significance for each of them, each of the attributes was initially rated in order of importance, the next step is to assign the rating to each of the proposals.

Table 2 shows the analysis carried out by the CBA method for the selection of the best alternative for the Housing project. The analysis is made from the evaluation of criteria such as innovation, investment of economic resources, duration of each Project, temperature oscillation, the comfort of the property, the losses and gains of heat, and the most important criterion, the consumption of annual energy of each of the alternatives. Alternative 2 exceeds the level of significance to alternative 1 since the highest weighting of the factors was assigned to the annual KW electricity energy consumption factor, which was decisive for the selection, where alternative 2 obtained a value of 250 points versus alternative 1 that only reached a value of 150 points respectively, which confirms the provisions of the previous models made with the DesignBuilder software, but from another perspective.

The respective budgets of each of the alternatives were developed independently, obtaining as a result that the adjustments of alternative 2 had an extra cost in relation to alternative 1 in a value of $ 7,602,060 Colombian pesos (COP). As indicated in [21,22], Figure 6 shows the analysis of costs and the payback period [23], for the investment made. The initial investment with which it is expected to generate a reduction of 18.92 KW·h/m^2 has a return period of 10 years, since the income is of a linear type with a value of COP 760,206, achieving a balance in said evaluated time; from year 11 only income is generated. Taking a construction life span of 100 years, income of COP 76,020,600 is achieved.

Table 2. Choosing by advantages method for project.

Factor / Criterion	Alternative 1 Housing in initial conditions		Alternative 2 Housing in final conditions	
Innovation	Greater use in buildings		Less use in buildings	
Less is better	Less frequent use of technology	50	More frequent use of technology	0
Investment ($)	Lower investment		Greater investment	
Less is better	Investment cost reduction	50	Increased investment costs	0
Employment (Days)	Shorter duration of the work		Longer duration of the work	
Less is better	Shorter duration in activities	50	Moderate duration in activities	0
Oscillation (%)	Greater oscillation		Less oscillation	
Less is better	Greater oscillation in the Tº	0	Less oscillation in the Tº	50
Comfort (%)	Nonconformity		Nonconformity	
Greater is better	Less comfort	0	Greater comfort	50
Loss / Gain (KWh/m²)	Greater losses		Lower losses	
Less is better	Reduction of energy gains	0	Greater energy gains	50
Annual consumption of (KWh/m²)	Higher Consumption		Lower consumption	
Less is better	Greater consumption of electrical energy	0	Reduction in the consumption of electrical energy	100
TOTAL		150		250



Figure 5. Cost analysis.

4. Conclusions

With the completion of the life cycle analysis, it was possible to see how, in the short term, the emissions generated by the construction of alternative 1 are lower due to the fact that fewer materials are used for its construction, but when analyzing the 100-year useful life of the housing the use of the improvements reduces the emissions of Kg of carbon dioxide equivalent by 17%. Additionally, with the implementation of the changes in alternative 2, it was possible to obtain a reduction of 66% in annual energy consumption in the property.

Applying the choosing by advantages selection method, alternative 2 exceeds alternative 1 by twice the significance value, because in this analysis the reduction in equivalent Kg of carbon dioxide emissions was of greater importance. The results obtained allow us to verify how the implementation of small changes in the construction of the houses manages to significantly reduce the emissions generated and therefore convert a normal construction into a sustainable one. The above indicates the need to promote responsible energy consumption, through the implementation of improvement processes in the construction sector, so that a contribution is made to the environment with the reduction of carbon dioxide emissions and the reduction of costs in the value of electrical energy consumption. Future research is expected to extend the analysis to educational, industrial, and commercial construction projects.

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